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A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the plantations of the Hawaiian Sugar Planters' Association.

In This Issue:

Poison Bait for Armyworms and Cutworms:

An account of an improved poison bait for use against armyworms and cutworms on plantations subject to heavy rains is given.

Rate of Cane and Sugar Formation in Cane Crop:

This short note presents our latest views on the rate of cane and sucrose formation in a field of cane. It is pointed out that the highest rate of sucrose storage follows very closely upon the highest rate of cane formation, which latter, as we all know, occurs between the age of six to twelve months.

Water-Stage Register for Plantation Field Ditches:

A simple and inexpensive water-stage register designed and constructed by the agricultural department of the Station is described. Since the preparation of this paper, thirty-four instruments have been manufactured and delivered to plantations at cost. Although similar in general plan, the instruments are somewhat simpler than the model illustrated.

The performance of these devices is being watched with interest.

Use of Thallium Torpedoes:

Some further evidence is given that thallium torpedoes treated with corn oil are attractive to rats.

The bad odor sometimes developing in the torpedoes is thought to be due to excessive direct heat to the paraffin bath during dipping.

Weather Charts for Plantation Use:

In this article, one of our plantation managers details how he keeps records of the weather conditions affecting his crops, and sets forth various ways in which the

recorded information can be used to greatest advantage in directing plantation policies.

Some Physical Constants for Cane Soils:

Although it has long been known that the physical and chemical nature of a soil depends largely upon the conditions of weathering under which the soil is formed, local work in this field has been meager.

The present paper reports the value of six physical constants and the results of two chemical determinations for seventeen soils secured from Hawaii and Maui. Some of the results are presented in graphical form.

It is evident that the highly productive soils of Maui are characterized by high apparent densities, low ignition losses and high ratios of SiO_2 to Al_2O_3 and R_2O_3 in the colloidal material. Soils from the Hamakua coast carry high percentages of material which may be lost on ignition and relatively high percentages of colloidal organic matter. As is well known, these soils fix P_2O_5 markedly. The soils from Kohala form a third group, which is more similar in its properties to the Maui soils than to the other soils from Hawaii.

Soils from certain "growth failure" areas are similar to near-by productive soil in all measured characteristics.

Strengthening Lime Mortar by Addition of Molasses:

It has long been known that the addition of sugar or molasses to lime mortar will increase the strength of the mortar. The investigation here reported presents definite data on the beneficial results obtained by adding molasses to lime mortar.

Poison Bait for Armyworms and Cutworms

As a supplement to the standard arsenical dust for use against armyworms as described on pages 5-6 of *The Hawaiian Planters' Record* for the first quarter of 1933, the following bait has been found to be an improvement over former baits used:

10 pounds bagasse
20 pounds molasses
1 pound white arsenic
½ pound casein (Kayso)
2 quarts water.

Before the ingredients are mixed together the arsenic is first stirred into the molasses.

The new feature of this bait over others formerly used in Hawaii is the inclusion of casein in the mixture. This has been added at the suggestion of Dr. F. E. Hance, chief chemist of this Experiment Station. The casein greatly improves the coherence of the particles composing the mixture and adds to its life very considerably by preventing breakage, scattering and washing away when beaten upon by drenching showers of rain. Raymond Conant, of Olaa Sugar Company, Ltd., prepared such a bait and tested it at the Mountain View section of the plantation with entirely satisfactory results.

In armyworm warfare we now have two poison methods of control which should not be confused. The poison dust mixtures, made and applied in accordance with the instructions given in the last issue of the *Record* will continue to be the most generally used and most satisfactory in combating nearly all outbreaks of armyworms. This applies especially to the nutgrass armyworm *Spodoptera mauritia.* However, there will be times when the other armyworm, *Cirphis unipuncta,* will become destructive, especially during periods of heavy rain. The bait above described should prove useful against this insect, particularly because many of them usually occur on the ground during the daytime. This bait will also be of importance in controlling certain cutworms in gardens.

C. E. P.

Rate of Cane and Sugar Formation in a Cane Crop

By U. K. Das

Following a recent request, I have herein attempted to set down our ideas on "how cane and sugar are formed as the crop proceeds." Though the data particularly relate to H 109, it is believed that the general consideration will apply equally well to other varieties.

Generally a crop is complex in its composition. At any period, it contains stalks of various ages, each age group forming cane and sugar at different rates. For the sake of clarity, then, we may omit for the moment the discussion of what happens to a crop, and take up the question of what happens to a single joint of cane, which is the most readily discernible unit of a cane crop.

A joint that has just completed its length (and is almost completely developed) contains little or no sugar. Under ordinary conditions, the sugar storage in that particular joint must follow very readily the completion of vegetative growth, for we find that by the time the leaf attached to that joint has dried up or dropped off, that joint has reached a certain state of maturity. (Our present information is that this joint may accumulate a little more sugar as time goes on. But this amount will be only a small fraction of all the sugar that is in that joint.) In support of this statement we may cite the numerous joint-to-joint analyses of Brix that we have made in the past few months, of which a few representative data are shown in the accompanying illustrations.

If we assume the longevity of a leaf from the time it fully develops to yellowing or dying off to be about two to three months, then, we should expect the storage of sucrose in a particular joint to be more or less completed in about two to three months after it has been formed.

From considerations of a single joint of cane, we may now proceed to the consideration of a single stalk of cane. As we all know, a stalk of cane grows at varying rates depending on its age. Its rate of growth is also influenced by the environmental condition of weather and culture. But keeping in mind what we said about a single joint, we may conclude that the rate of sucrose formation will follow closely the rate of cane formation—lagging behind by two to three months. Several years ago, the writer established that independently of other factors, and under optimum cultural conditions, the rate of length growth in an average primary stalk of H 109 cane was the highest between 6 to 10 months of age. We would then expect the rate of sugar formation also to be highest between, say, 8 to 12 months of age.

From consideration of a single stalk of cane, we may now take up the question of a crop of cane. As has been said previously, a crop at any stage of development is complex in its composition. An estimation of rate of sucrose formation in a cane crop is, therefore, a little more complicated. But we may again apply our analogy and say that the highest rate of sucrose accumulation will follow with due

lag the highest rate of cane formation. Fortunately, for us, we have some data from Waipio Experiment E to substantiate our claims.

In this experiment cane was planted in the different seasons and aliquots of the area harvested at different ages. The average rate of cane formation and sucrose storage was, then, calculated for various ages.

The data are presented graphically in Fig. 4. There we see that the rate of increase in cane tonnage per month was highest between 6 to 9 months, and that the monthly rate of increase in tons sugar per acre was highest between 9 to 12 months of age. In other words, the highest rate of sugar accumulation lagged about three months behind the highest rate of cane formation. We therefore conclude that (contrary to popular belief) sucrose storage goes on at the maximum rate soon after the cane growth has reached the maximum; in other words, in the earlier months of a cane crop.

In all these discussions, we have considered the rate of sucrose storage only and not the total amount of sugar stored. This latter will generally increase with the increase in tonnage of a cane crop. Data from Waipio Experiment E show that this maximum amount is reached for plant H 109 cane at about 24 months of age.

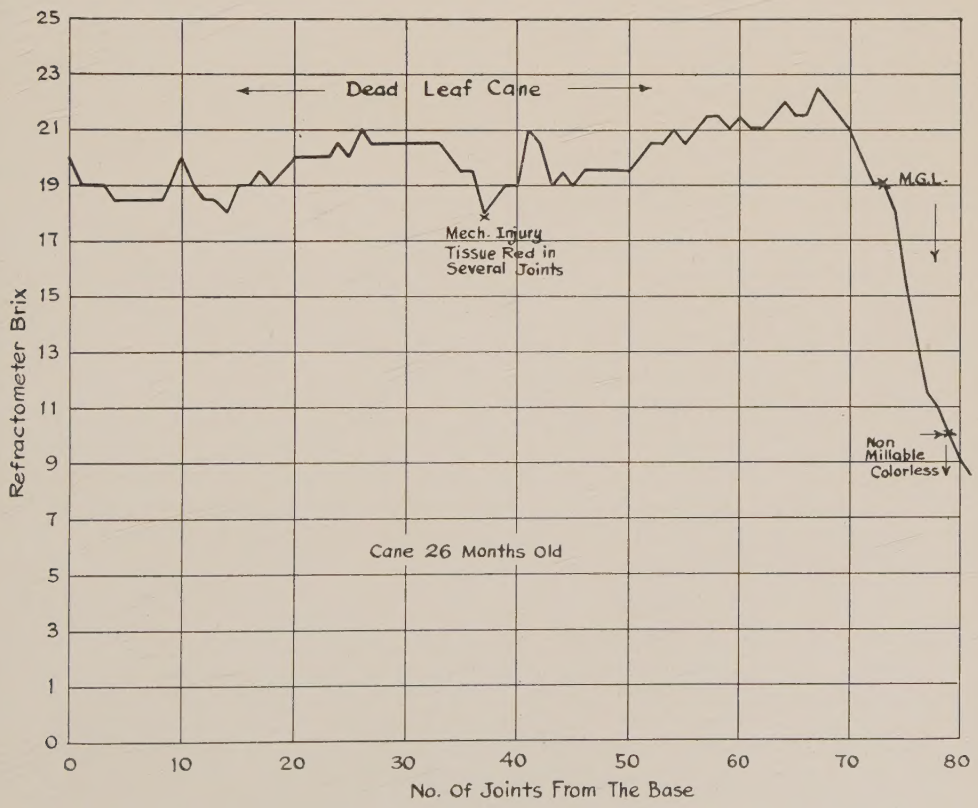


Fig. 1

(For legend, see Fig. 3)

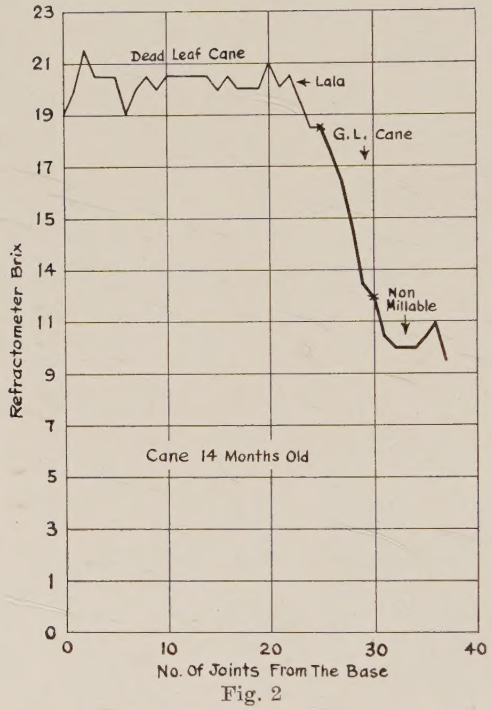


Fig. 2

(For legend, see Fig. 3)

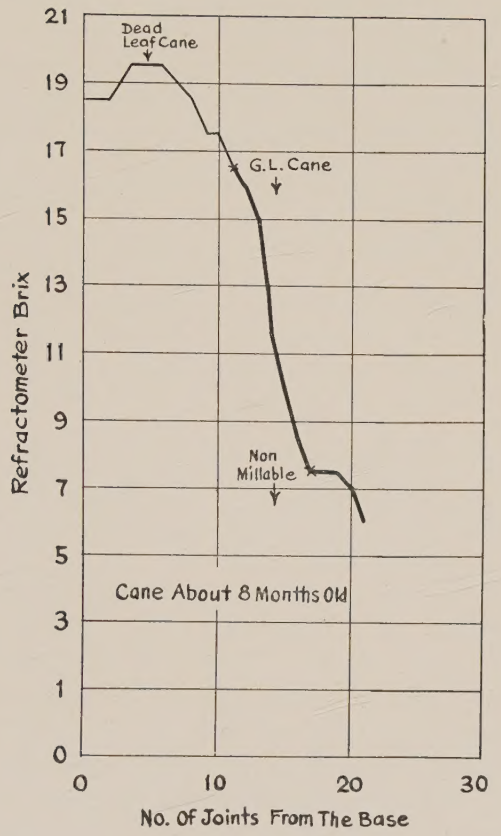


Fig. 3

In Figs. 1, 2, and 3 it will be observed that the recently formed joints just below the M. G. L. (millable green leaf) section have almost as much Brix as the joints near the bottom, which latter were formed weeks and months before.

The joints in this M. G. L. section are, however, still very immature. As there is only an interval of two or three months separating the M. G. L. section from the top end of the dead leaf section, it is easily concluded that the rate of sucrose accumulation is very rapid in this M. G. L. section, which has just passed through its period of the most active vegetative growth.

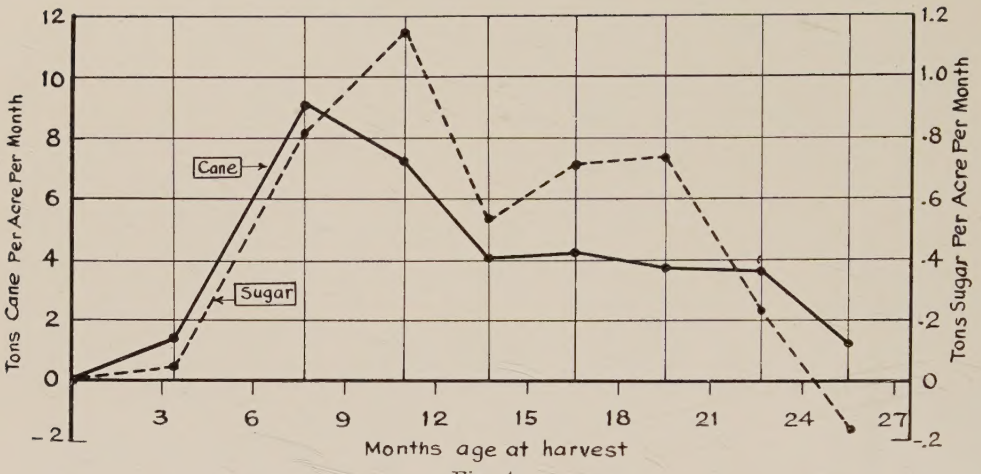


Fig. 4

The point of interest in this figure is that the rate of cane and sugar formation is very slow at first, then the rate rises very rapidly, to be followed by rapid decline. It shows that between 9 and 12 months of age the average crop in this experiment was making sugar at the rate of 1.2 tons per month, while between 6 and 9 months the average crop was making cane at the rate of 9 tons per acre per month.

The practical implication of these great variations in rate of growth at different ages must be clearly borne in mind in any progressive cultural policy on a plantation.

An Inexpensive Water Stage Register for Use on Plantation Field Ditches

By H. A. Wadsworth

A locally designed water stage register has been built for use on field ditches where the necessary precision of measurement does not justify the significant investment represented by the installation of one of the instruments now on the market. Since any water-measuring structure operates at low efficiency unless equipped with some form of recorder, the need for an inexpensive instrument for this purpose has long been apparent.

For two years the Experiment Station, H. S. P. A., in cooperation with the Physics Department of the University of Hawaii, has been developing such a device. The model which was exhibited during the last annual meeting of the Hawaiian Sugar Planters' Association employs no untried principles in instruments of this sort; it is simple, sturdy, inexpensively built, and promises an accuracy of record which is quite in line with the requirements of field measurement.

Like some devices of the sort, the record paper is used to cover a cylindrical

drum which rotates in its bearings under the action of a float riding in a properly located stilling well. The pencil moves along this drum under the action of a falling weight and under the time-control of a cheap clock. The clock simply acts as a brake regulating the speed of the pencil but does not drive it in any sense.

A cheap, readily replaceable clock has purposely been selected, it being thought that money for clock repairs might be better spent in the purchase of a new clock than in trying to repair an old one. Any eight-day clock, particularly a compact, eight-day alarm clock, may be used. The clock is attached to the bed plate by two thumb screws, which permit prompt replacement. A cheap clock of German manufacture has given satisfactory service for more than twenty weeks without attention. The clock costs $2.50.

The accompanying illustrations show the set-up from three points of view.

The instrument illustrated has been in field use on a Maui plantation since its exhibition last winter. In a letter under date of April 17, 1933, the manager of that plantation says:

> From all indications the instrument appears to be quite satisfactory for plantation flow measurements. It has run continuously since being set up in the field on December 23, 1932. An examination of the charts shows the time and gage height to be very close to the correct spot at the end of a week's run.

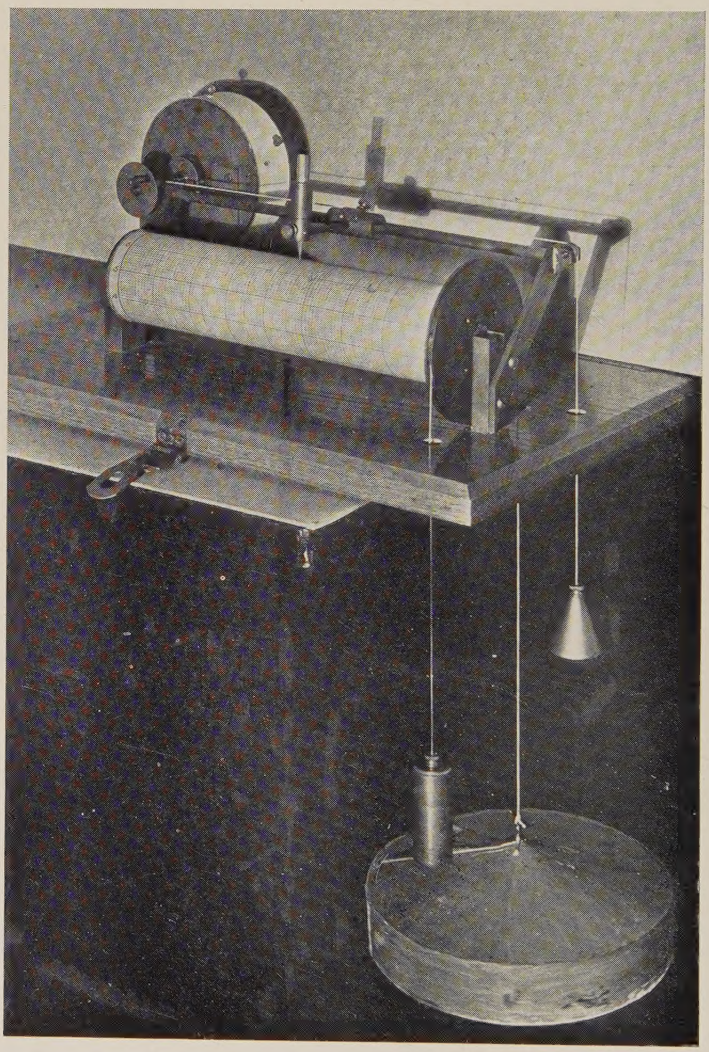
Present plans call for a minor modification in design. This involves installing a double pulley on the float end of the drum in order that the device may record in either a 1:1 ratio or 1:2 ratio. When the larger pulley is used, a head fluctuation of two feet may be accommodated with a single revolution of the drum.

Two plans have been proposed with respect to the construction of the instruments which may be needed. One of these involves their construction in plantation shops by plantation employees. In the furtherance of this scheme the Experiment Station stands ready to extend whatever aid it may in the preparation of working drawings and in lending for short periods the working model for replication.

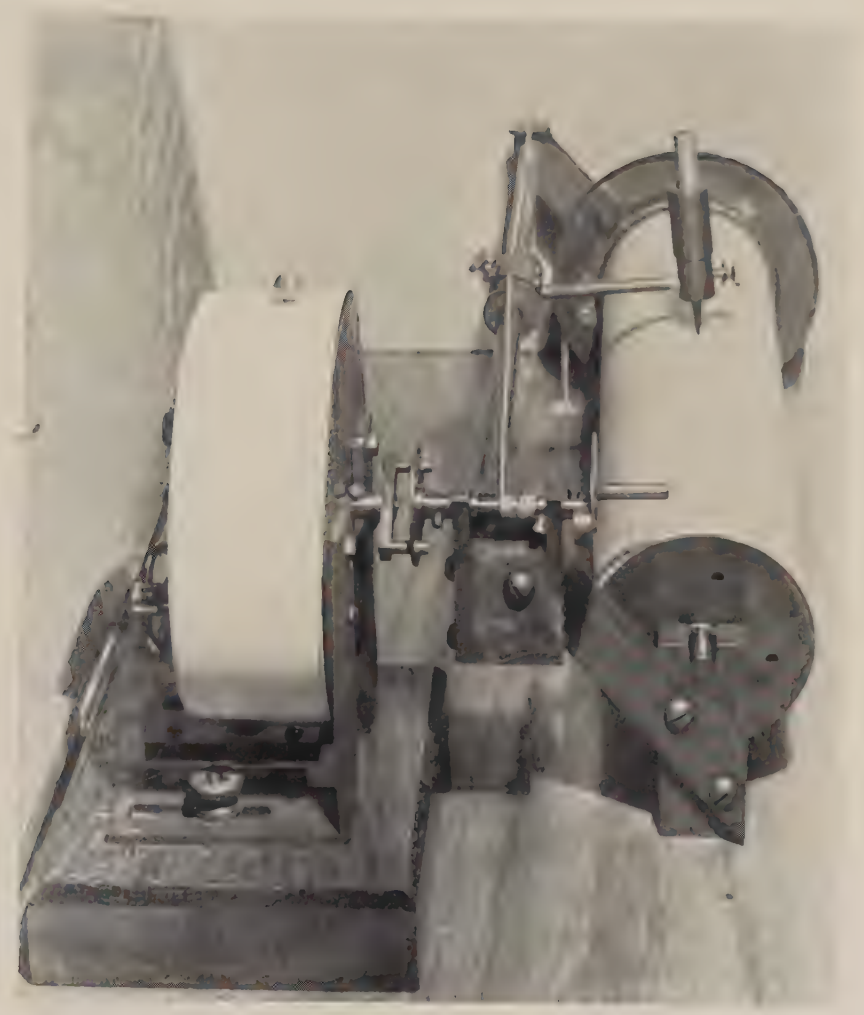
The other possibility involves the construction of the instruments in Honolulu under the supervision of the Experiment Station, and their subsequent distribution to interested plantations or agencies at cost. This scheme has the advantage of supplying uniform instruments as well as a source for standard replacement parts. Moreover, certain economies may be effected by production in numbers. Rough brass castings in certain parts would greatly lower the price if enough instruments were ordered to justify the patterns.

Preliminary cost figures, based upon the assumption that castings are to be used, indicate that the completed device will cost about $32.50 if made in Honolulu and distributed at cost. This charge includes material as well as the prorated charge for the patterns and payment for the time of the instrument maker in assembling. It should be said that greatest precision is required in at least two operations in the construction.

Some of these instruments are now being made on orders from plantations.



General view of the original model of the locally built water stage register showing float and counterpoises.



Detail of clock end of the register. Note that the pencil is drawn across the drum by the falling weight. The clock regulates the rate of the pencil's motion, but does not drive it.

Some Notes on the Use of Thallium Torpedoes

By R. E. Doty

A number of corn oil-paraffin torpedoes were checked against straight paraffin torpedoes at the Waipio substation recently. The corn oil-paraffin torpedoes were placed alternating with the straight paraffin torpedoes, each spaced some 8 to 15 feet from any other, along the edge of big cane. In some cases they were placed close to the base of fence posts, where they could be located easily.

To facilitate the counting and recording, these torpedoes were placed in groups of 20 of each kind. Ten of these groups were put out at one time, making a total of 200 of each kind in a series. Three such series were placed and gathered up again at the end of 36 to 40 hours.

The summary of these results are given herewith:

	No. Laid Out	No. Recovered	No. Nibbled	No. Taken Up
	Feb. 2, 1933			Feb. 4, 1933
Paraffin torpedoes	200	184	4	12
Corn oil-paraffin	200	115	21	64
	Feb. 6, 1933			Feb. 8, 1933
Paraffin torpedoes	194	162	11	21
Corn oil-paraffin	199	61	62	76
	Feb. 8, 1933			Feb. 10, 1933
Paraffin torpedoes	200	183	11	6
Corn oil-paraffin	200	97	77	26
Totals—Paraffin torpedoes	594	529	26	39
Corn oil-paraffin	599	273	160	166

It should be noted here that there were very few rats throughout most of the area used in this test. The area along the algaroba grove appeared to be thickly infested.

There was a total of only 39 straight paraffin torpedoes taken compared with 166 corn oil-paraffin torpedoes taken. This furnishes some additional data that corn oil lures the rats to the poison bait.

Notes from Kauai

C. C. Barnum reports that there were a number of cases where the rats were not taking the bait as formerly. Other complaints stated that the torpedoes had a bad odor and ceased to be as attractive as before. The difficulty was traced to burned paraffin which had been decomposed by excessive direct heat.

Paraffin melted over an open fire often becomes overheated to the point of smoking. In this case the paraffin breaks down, becomes yellowish in color and develops a bad odor and is apparently unpalatable to the rodents.

This condition may be overcome by melting in a water bath. Straight water at boiling is not quite hot enough if the dipping of torpedoes is proceeding rapidly. Dr. F. E. Hance recommends that this feature may be overcome by using a mixture of water and commercial radiator glycerine in proportions ranging from one part of glycerine to three parts of tap water up to 3 parts of glycerine to 1 part of water. A temperature of approximately 125° C may be obtained with the mixture of 3 parts of glycerine to 1 part of water. A predetermined mark should be made on the side of the container and water should be added at intervals to bring the level of the bath up to this mark. This solution will last indefinitely if this procedure is followed.

The amount of corn oil in the dipping mixture should not exceed more than 25 per cent by weight, or the paraffin will not harden sufficiently to be waterproof.

Considerable difficulty is being experienced with ants and cockroaches eating holes into the torpedoes. In this case it would seem advisable to materially reduce the amount of corn oil in the mixture or perhaps dip in pure paraffin and then spray corn oil on the torpedoes with a flit gun, as has been done at Honokaa Sugar Company and Hutchinson Sugar Plantation Company.

Weather Charts for Plantation Use

By W. L. S. Williams
Manager, Waiakea Mill Company

Importance of Weather Factors on Yield

It has always been recognized that the weather plays a very large part in the production of crops, but just how large this part really is has probably not been fully realized up to this time. Das* has shown that at Pepeekeo fully 80 per cent of the variations in yield from year to year can be attributed to variations in weather conditions. Here at Waiakea, we feel that weather exerts as much, and probably even a greater, influence on yields.

For many years past, all plantations have kept faithful records of rainfall, but it was only five or six years ago that the tremendous influence of slight changes in temperature was first recognized, and it is only within the past year or two that any marked attention has been paid to the factor of sunlight. In certain districts, the velocity and direction of the wind will also be a factor which must not be overlooked. The studies made by Das, first at Pepeekeo and later at Ewa and Honokaa, have been outstanding, and have led us, at Waiakea, to make a small beginning in attempting to reduce the main weather factors to numerical indices which can be graphically shown in chart form.

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* Das, U. K. 1932. A Further Study of the Influence of Weather on Yield. *The Hawaiian Planters' Record*, Vol. XXXVI, No. 1, pp. 40-59.

We all recognize that good weather assists in crop production while bad weather retards our field work. We need warmth and sunshine to start a young crop on its way. We like to see heavy rains well distributed throughout the summer so that the year-old cane will make a vigorous growth. We want dry, sunny weather shortly before and during harvesting to improve juice quality. We all talk about the weather, and when two plantation men meet it is usually one of the first topics of conversation. But aside from keeping rainfall records and possibly noting the maximum temperatures each day, very few of us have really kept any definite weather records in a form readily available for comparison with previous years or the average of past years' observations.

It will be said that there is little profit in keeping definite weather records, as climatic conditions are beyond our control and charting the weather will not improve conditions in any way. We believe that weather data are fully as important as data on field areas. Our acreage is just as much beyond our control as is the weather, and various parts of any plantation probably vary as much over and under the average as weather conditions depart from normal from year to year. Yet we all keep careful and detailed account of our crop areas, express our yields in terms of tons of cane and sugar per acre, and feel that we would be entirely at sea if we did not have accurate maps of our plantation fields. In time, we believe, those responsible for the efficient operation of our plantation properties will feel the need of complete weather data and charts as much as they now require tabulations of field areas, maps and soil surveys, both for the operation of the individual plantations and also for the intelligent comparison of the results obtained on one plantation with the costs and yields on another.

Without definite weather data and charts, our conception of the weather will be largely a matter of personal opinion, and opinion is largely influenced by recent events to the exclusion of those more remote. If we have had several weeks of dry, hot weather, we are very apt to exaggerate in our own minds and feel that we are being afflicted by a severe drought, while a month or so of wet weather will wipe all thought of the drought from mind and possibly lead us to assume an overconfident outlook. However, we usually are prone to exaggerate bad weather and feel this more keenly than good weather. When a drought comes along, we lay all the blame for poor yields to the bad weather, while the good yields caused by a period of good weather are very easily attributed to our improved varieties, better methods of cultivating and fertilizing, and more efficient management in general. If weather charts do nothing else, they will do away with personal opinion and permit of fairer comparisons, as well as give a very accurate indication of the trend of yields and the efficiency of cultivation on any plantation, and allow us to know definitely whether weather conditions on any crop have been above or below normal, thus acting as a check on crop estimates.

Measurement of Weather Factors

About six months ago, prompted by the work done by Das at the Experiment Station, we began collecting all available weather data at Waiakea, and have attempted to assemble these data in a fairly simple manner so that comparisons

could be made from year to year. Available rainfall records for one station went back to 1906, but this was at the mill and not representative. Our other two stations were established in 1914 at 600 and 1100 feet elevations. This gave us very complete rainfall data for 18 years. Maximum and minimum temperature records were started at our 600 foot station in 1928, and at the 25- and 1100-foot stations in 1932. As the observations at the 600-foot station were very uniformly the approximate average of the other two readings each month, we have used only the one reading for temperature. No correlation with Hilo observations has been possible on temperature, so no use could be made of the Hilo records, which go back many years, and we have only five years of temperature records on which to base our work.

No sunshine records have ever been kept at Waiakea, and for this important item we have to use the Hilo records, with an arbitrary correction factor applied, in an attempt to approximate our own conditions. With these very sketchy data available, it is manifestly impossible to obtain quantitative results, and all we have hoped for is to make a start which may later be improved as more data accumulate from year to year. In order to assist in eliminating some of the errors which naturally will be present in data of this kind, we set up a series of assumptions which have been used uniformly throughout the work. Using these assumptions and the average monthly rainfall, temperature and sunlight data available, we then calculated and charted a normal weather curve. Using the same assumptions and the monthly data for various crops, we next calculated and plotted the weather curve for each crop. A comparison of the *normal* with the *crop* curves would then tend to cancel errors in the assumptions and in the basic data, and we believe the work done and the methods employed will be of future benefit to us and may possibly be of interest to others.

Rainfall

At Waiakea the rainfall is so heavy, averaging almost 20 inches in some months and having exceeded 50 inches per month on certain occasions, that it is obvious that the total rainfall cannot be considered effective on the growth of crops. With young cane we have noted a decided advantage in starting under fairly dry conditions, and even year-old cane should not be expected to utilize anything like 50 inches of rain in 30 days. An experiment at the Makiki plots, where cane was given irrigation at the uniform rate of 16 inches per month, was designed to give the cane all the moisture it could absorb. Considering the porous nature of our soils, we have assumed that a 20-inch rainfall per month would be effective on cane nine months old or over, that is, after closing in. Prior to closing in, we have assumed that young growing cane could absorb increasing amounts from month to month, and have arbitrarily set 2 inches as the effective rainfall for the first month after harvesting or planting, increasing this to 3, 4, 6, 8, 10, 13, 16 and 20 inches for the second to ninth month, respectively.

Using either the effective rainfall limit as shown above or the actual rainfall figure, whichever is the smaller, we can then calculate the "effective acre inches" for any crop by multiplying the area under cultivation in any month by the effective

inches of rainfall for that month and accumulating these monthly figures from the start of the crop until harvest. For instance, if 300 acres of the 1933 crop are cut in January, 1933, and there are 18 inches of rainfall that month, the "effective acre inches" for the first area of the 1935 crop will be 300×2 or 600 acre inches, the additional 16 inches being considered not effective. Similarly, if another 300 acres is cut in February, and rainfall is 12 inches that month, the "effective acre inches" for February will be (300×2)+(300×3) or 1500 and the "effective acre inches" to the end of February will be 1500+600 or 2100.

It has been pointed out by Das that the effective limit of rainfall will vary, depending on the temperature, sunlight and wind movement, but considerations of this type introduce so many complications and the method herein outlined is so rough in any case, that these effects must be considered unavoidable errors and within the limit of error of the whole system.

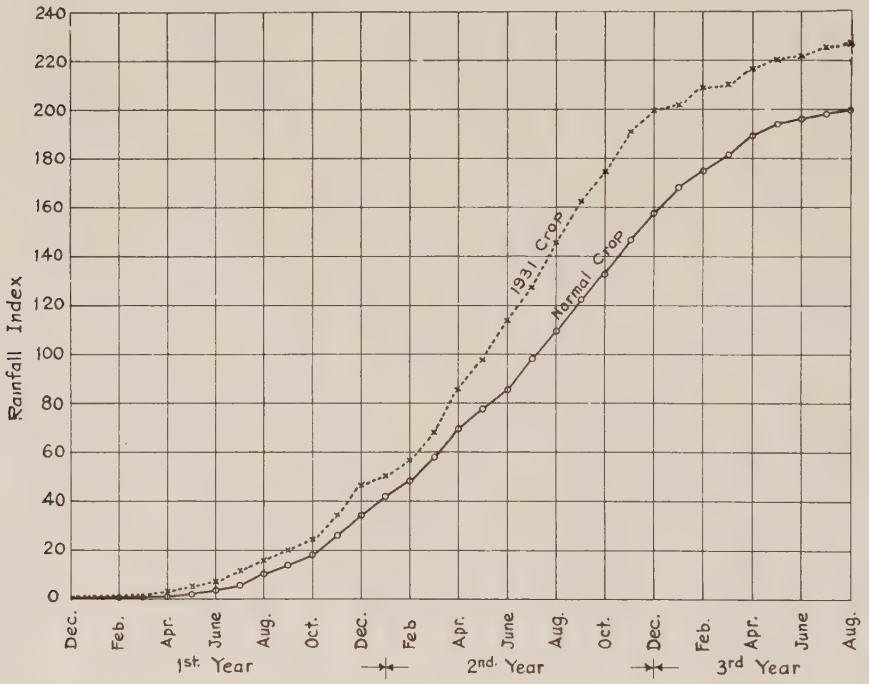


Fig. 1

Temperature

Following the method suggested by the Experiment Station, we measure effective temperature as degrees Fahrenheit above 72 degrees of mean maximum temperature. The base line of 72 degrees is admittedly arbitrary but it appears to agree well with our observations and it may later be modified if future observations seem to warrant a change. Using this base, we calculate what may be called "effective acre degrees" of heat, which is simply the area under cultivation multiplied by the effective temperature for the month. In this case we assume one degree of heat to be as effective on young cane as on old cane, though here again

refinements might be possible did they not introduce such complications into the calculations. As above, the monthly figures of "effective acre degrees" of heat are accumulated from the start to harvest of a crop. As an example, if the area harvested in January is 300 acres and the mean maximum temperature for that month is 78 degrees, 300×(78—72) or 1800 will be the "effective acre degrees" for the month.

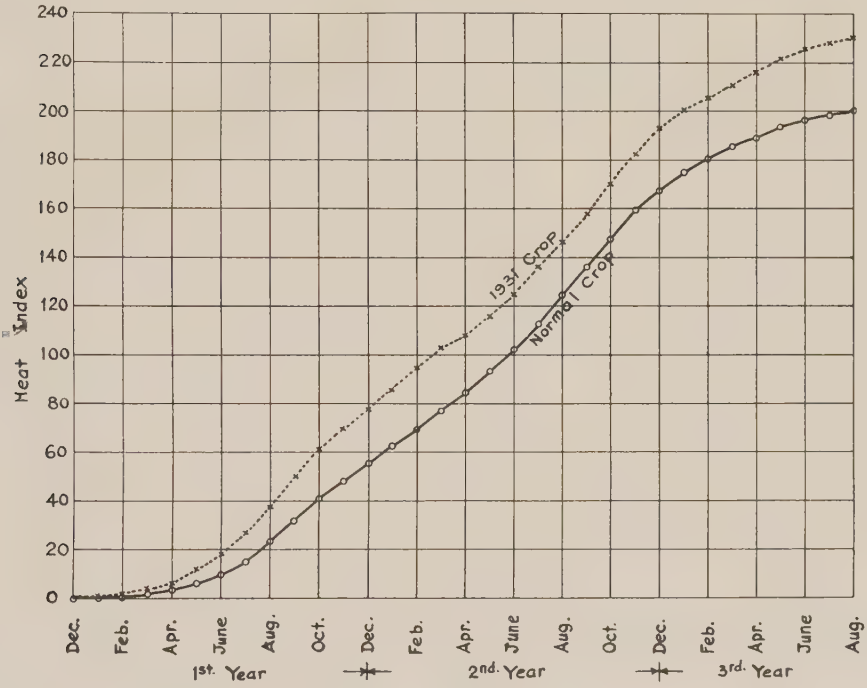


Fig. 2

Sunlight

As we have no figures for sunlight at Waiakea, we have used the data on record at the Federal Building in Hilo. These data are reported as so many clear, partly cloudy and cloudy days for each month. Assuming a clear day at Hilo to have about 40 per cent sunlight under average Waiakea conditions, a partly cloudy day 20 per cent, and a cloudy day 10 per cent, we can obtain an index figure for sunlight in the different months. If this index figure is multiplied by the possible hours of sunlight for an average day in any particular month, we obtain an approximation of the actual hours of sunlight per day at Waiakea.

Similarly as in the cases of rainfall and temperature, explained above, the area under cultivation multiplied by the sunlight index will give "acre sunlight hours," here again the assumption being that sunlight is as effective on young cane as on old cane. This assumption might also be criticized in that the effect of sunlight might be considered proportional to the total leaf area exposed to its effects, but here again we must plead simplicity as against strict accuracy.

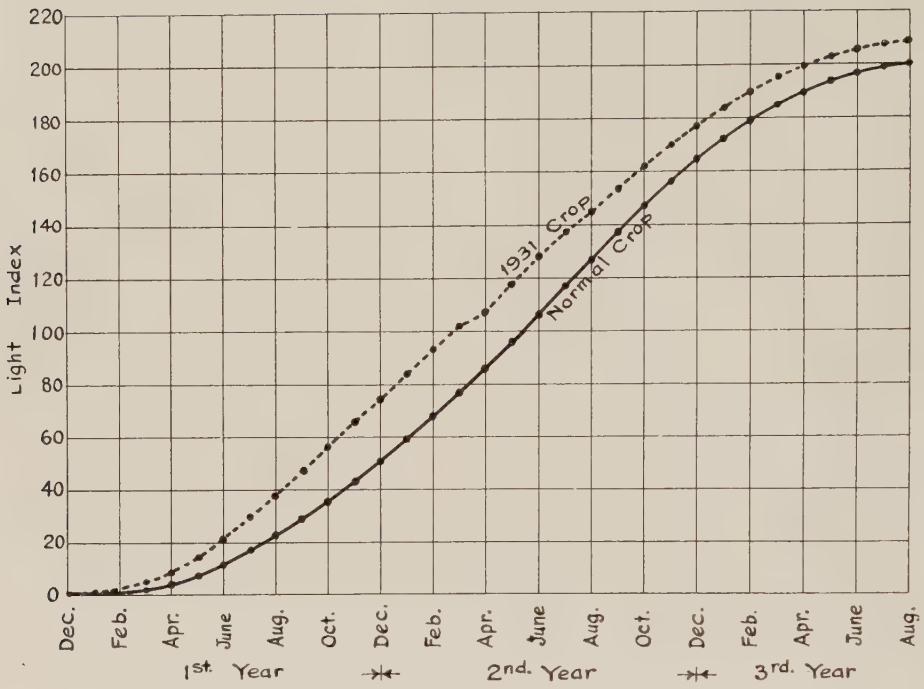


Fig. 3

Wind

At Waiakea we seldom have heavy winds. For this reason, we have not attempted to introduce this factor into the picture, assuming that the effect of wind will be uniform from month to month and from crop to crop. Any plantation where the wind varies greatly in velocity could not afford to make this assumption, however, and some inverse ratio of wind velocity would have to be used to complete the charts. Possibly a negative factor such as "acre miles" of wind travel might be developed.

Combined Effect of Weather

So far, we have considered rainfall, temperature and sunlight as separate factors. Until more is known about the relative values and importance of these factors, possibly it might be better to attempt to evaluate each factor separately as to its effect on yield. However, we have made one more assumption: that each of the three factors is of equal importance to crop production, and on this basis have attempted to combine all three factors into one unit which we may call our "Weather Index." It is as yet too early to judge whether this one figure will give us all the information that the three separate figures will, but we feel that in any case it is important to carry all four curves, as the interrelation of the different curves may lead to interesting developments on the prediction of juice quality as well as cane yield.

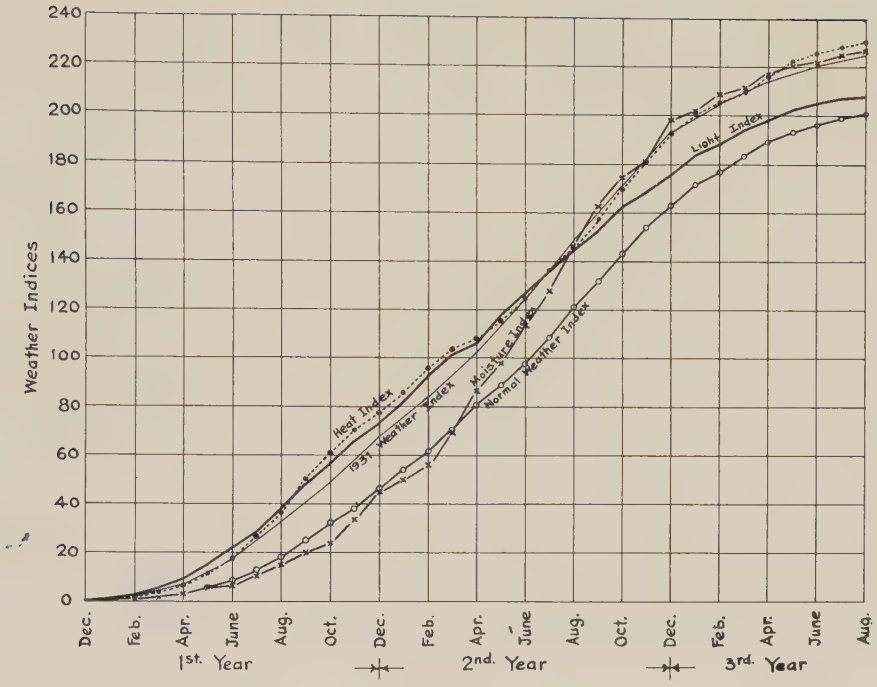


Fig. 4

Charts

Before plotting any of the figures, the derivation of which is outlined above, we have reduced all of them to a "per acre" basis. That is, "effective acre inches," "effective acre degrees" and "acre sunlight hours" obtained for each month are divided by the total crop area to obtain the corresponding figure "per acre." The figures so obtained are comparable from crop to crop and we term them, respectively, the "Moisture Index," "Heat Index" and "Light Index." As indicated just above, the combination of the three is termed the "Weather Index," and in this combination we assume that on the final yield of cane each component exerts an equal influence. In other words, we may say that each factor is responsible for fully one-third of the total weather influence and the "Weather Index" is the arithmetical average of the three subindices.

If the monthly indices outlined above are plotted on a chart against time, we have a series of curves which indicate the monthly variations in rainfall, temperature and sunlight, and the monthly weather curve. If weather exerts the powerful influence that we feel it does, this weather curve should closely follow the curve of growth measurements for any crop, and a good check on the accuracy of the assumptions could be provided by such a comparison.

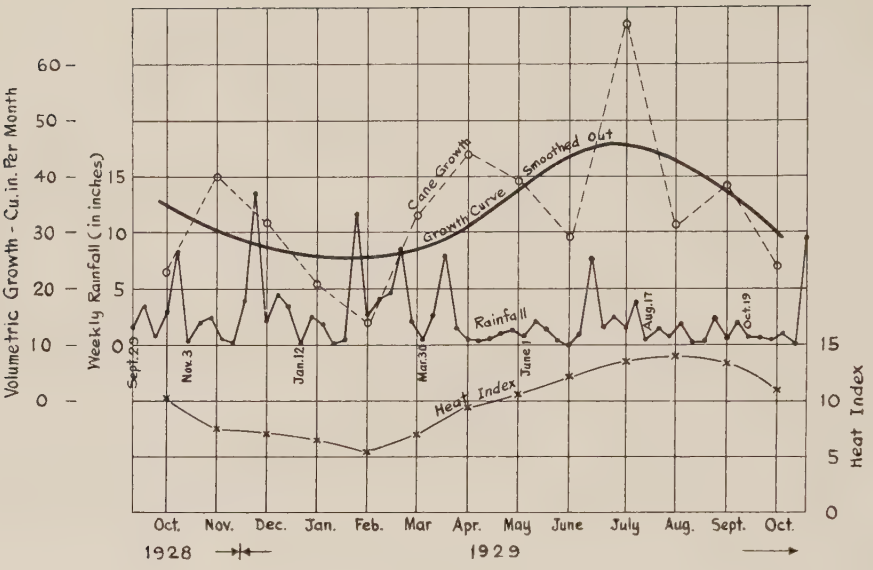


Fig. 6

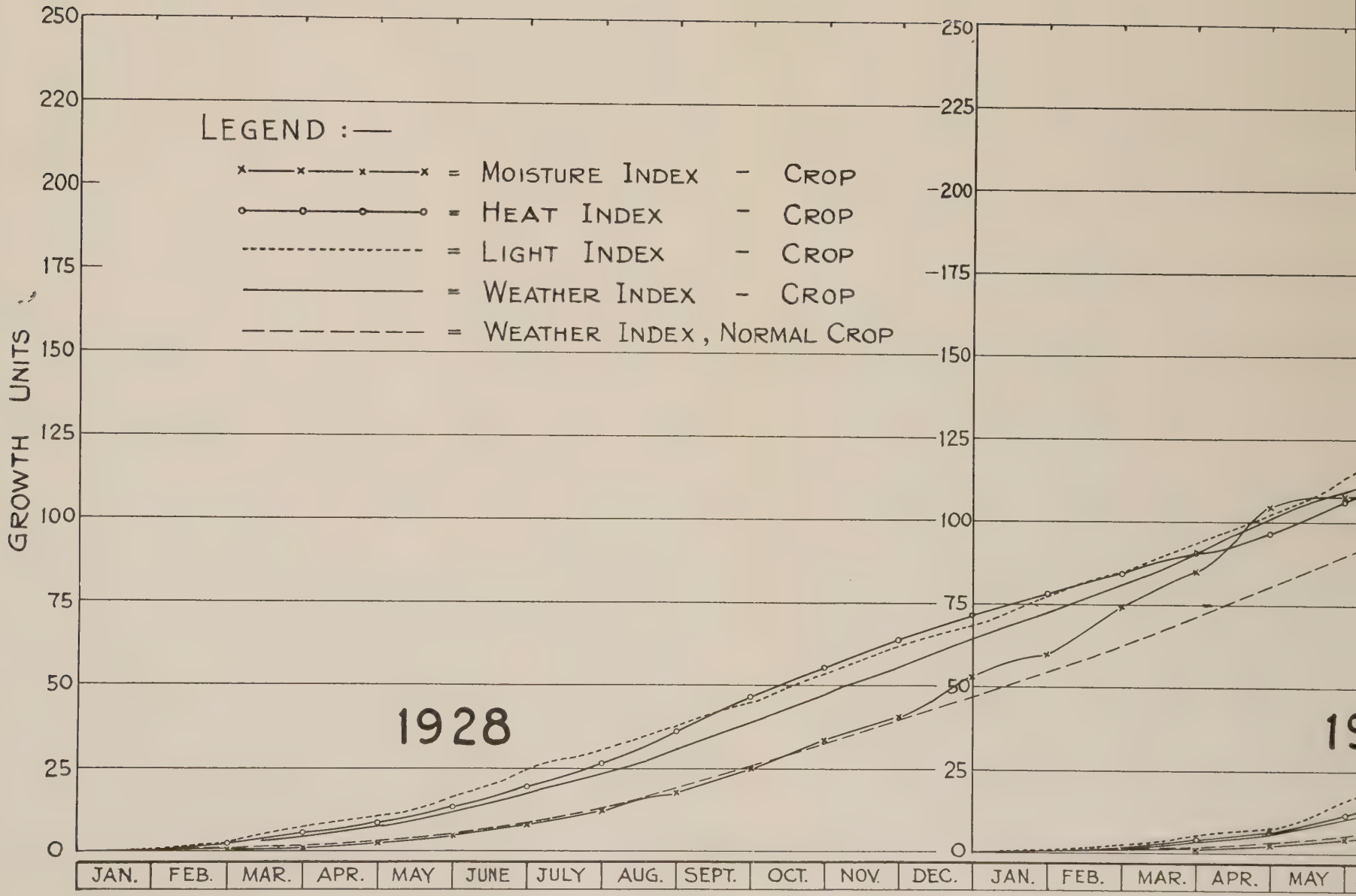
If the monthly index figures are accumulated and plotted on a chart against time, together with the curve of normal or average weather conditions made up as outlined in the early part of this paper, we have a comparison of current with normal weather conditions which is fairly accurate and which will tell at a glance whether any crop has had normal, subnormal or better than normal conditions from its start up to the time under consideration.

Weather charts accurately compiled should prove to be of great assistance to a manager in following his crop progress, in supplementing his visual observations as to the productivity of any one crop, and as a check on crop estimates, particularly on the first one made usually before harvesting is actually started.

Fig. 5 shows the great variations in the different weather factors we have experienced in the last few years.

Quality of Land

In this study at Waiakea, we have introduced a correction for the quality or fertility of the land area harvested from month to month. This seemed necessary to us due to the wide variation in the productivity of different types of land on this plantation. While this factor may vary as much as from 70 per cent of average in some months to 120 per cent of average in others, we find the maximum departure from normal for any crop to be not more than 1.5 per cent for the whole crop area. For this reason, while we feel that we must continue to use a corrective factor for land fertility at Waiakea, we do not believe this to be a significant figure, particularly for plantations whose area is more uniform. The determination of this factor requires more time than all the rest of the calculations put together, and it adds so many complications to the work as to render it more of a liability than an asset.


LEGEND :—
= Moisture Index - Crop
= Heat Index - Crop
= Light Index - Crop
= Weather Index - Crop
= Weather Index, Normal Crop
GROWTH UNITS
250
220
200
175
150
125
100
75
50
25
0
225
1928
JAN.
FEB.
MAR.
APR.
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.

Slope of Land

A recent article by Cornelison, appearing in *The Hawaiian Planters' Record* for the fourth quarter of 1932, indicates that a corrective factor for slope of land may be necessary to arrive at correct sunlight index figures. This factor might also be of importance with respect to prevailing winds and the rapidity of rainfall run-off in times of heavy precipitation.

Other Weather Factors

Besides rainfall, maximum temperature, and sunlight, which we have used in our calculations here, we have mentioned wind as a possible factor in some localities. There is also the factor of minimum temperature, which we have not used further than to record and chart it. This item should not be entirely overlooked, as there are indications pointing to a possible correlation between minimum temperature and cane ratio. The range of temperature is another factor which may prove significant on further study. The concentration of carbon dioxide in the atmosphere is still another factor which may be studied at some later time, having already had a certain amount of attention in Germany in connection with the forced production of certain crops under glass.

Conclusion

The small beginning that we have made in measuring crop progress in terms of weather factors makes us realize that in future it may be possible not only to express our yields "per acre," and "per acre per month," but also in terms of units of growth value, "effective acre inches of rainfall," "thousands of day-degrees," "acre sunlight hours" or as pounds of cane per "Weather Unit." Then only will it be possible to effectively compare one year's yield with another, one soil type with another, and one plantation with another.

Before closing, we wish to sound a warning to all plantations in the Territory and to those along the Hilo coast in particular. For the past five years we have had bumper crops. Records have been broken and broken again. We have all been taking a great deal of credit for improved methods of cultivation, better fertilizer practices and a general improvement in efficiency. This five-year period has been characterized by an abundance of labor. That is one factor. But still more important than the labor situation, we have had weather far above the average for each and every one of these five years. We cannot and must not delude ourselves into thinking and believing that the weather has changed permanently. There is no "New Era" in weather conditions any more than there was in economic conditions in 1928. For every year above normal there must be a year below normal, and the longer the good weather lasts the longer or the more severe will be the period of bad weather to follow. Just as surely as booms are followed by years of depression, just as surely are we heading for a "weather depression," and when that period of bad weather comes, and our yields fall back to more normal figures, it will be of some advantage to have our alibi prepared.

Acknowledgment

At this point we wish to express our appreciation of the work done by U. K. Das, of the Experiment Station, H. S. P. A., which really aroused our interest and started us on this investigation. Mr. Das has also outlined this article, assisted in its preparation, and prepared all the charts shown herewith for publication. Royden Bryan, of the Experiment Station, has helped us on the formulation of reasonable assumptions, while H. P. Agee has been of great assistance, giving his advice on many occasions and maintaining his interest in the progress of the work at all times.

Some Physical Constants for Certain Hawaiian Sugar Cane Soils

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By H. A. Wadsworth

Recent studies of some of the physical constants of representative samples of soil from the islands of Hawaii and Maui suggest interesting correlations which may aid in an understanding of some aspects of current cane-growing problems. For instance, it seems evident that plantations which are notable for low quality ratios and higher sugar yields are located on soils of high volume weight, or, speaking less accurately, on soils of high density. Another correlation of suggestive interest is that existing between the tendency of a soil to fix phosphate and the ratio of silica to the oxides of iron and aluminum in the colloidal separate of the soil.

It should be immediately recognized that no causal relationship is necessitated by such correlations. For example, cane of high quality may usually grow on soils of high volume weight, but it is not necessarily true that the good quality is due to the heavy soil. It would seem more logical to assume that the same characteristics of rainfall and temperature, which conspire to produce high sugar yields, are also factors in the production of soils of high volume weight. Nevertheless, the correlations are highly suggestive.

The soils used were collected during the summer of 1932 on the two eastern islands. Although listed by plantations and field numbers, it must not be assumed that the characteristics noted are typical of the entire plantation or even of the field noted. The samples were chosen to indicate typical regional conditions of soil formation and supposedly represent the entire range of weathering conditions and original materials. Eighteen samples were secured; seventeen of these were carried through the complete sequence of tests. The source of the soils used is given in Table I.

TABLE I

ORIGIN OF SOILS USED FOR MEASUREMENT OF PHYSICAL CONSTANTS

Soil Number	Island	Plantation	Field Number	Remarks
2	Maui	Maui Agric. Co.	Field 1	H. S. P. A. Nursery
3	Hawaii	Honokaa Sugar Co.	Homestead Field 1	P_2O_5 deficient
4	Hawaii	Hilo Sugar Co.		H. S. P. A. Station
5	Hawaii	Union Mill Co.	Kynnersleys 97	Experimental Area
6	Maui	Maui Agric. Co.	Field 84	High producing
7	Hawaii	Niulii M. & P. Co.	Field 27	
8	Hawaii	Laupahoehoe Sugar Co.	Field 5E	P_2O_5 fixation
9	Hawaii	Olaa Sugar Co.		P_2O_5 fixation
10	Hawaii	Olaa Sugar Co.		P_2O_5 fixation. Rich in organic matter.
11	Maui	Wailuku Sugar Co.	Field 68	No fertilizer except N.
12	Hawaii	Pepeekeo Sugar Co.	Field 6	High producing
13	Maui	H. C. & S. Co.	Field 3	High yield after fallow
14	Hawaii	Honokaa Sugar Co.	Homestead Field 1	Hollow
15	Maui	Maui Agric. Co.	Field 85	Growth failure
16	Hawaii	Pepeekeo Sugar Co.	Mud flow	
17	Hawaii	Hamakua Mill Co.	Field 27	P_2O_5 fixation
18	Hawaii	Hamakua Mill Co.	Field 26	H. S. P. A. composite

Since the physical constants usually used for soils may not be familiar, a brief description of what each represents is necessary. The following constants were measured:

(1) *Volume Weight:* This is the weight of a unit volume of soil, when the weight is expressed on the basis of oven-dry soil. In the present study a large diameter glass tube of known volume was filled with air-dry soil. The weight of this soil *after oven drying,* divided by the known volume, gives the reported volume weight. This method is arbitrary and is not to be confused with that used in the measurement of volume weight under field conditions.

(2) *Ignition Loss:* An oven-dry soil is one which has been dried at about 110° C. for 24 hours. There is no assurance that a significant further loss of weight might not occur if the temperature were increased. This additional loss might consist of organic matter burned away at the high temperature, water of crystallization and water so tightly held to the grain surfaces that only a high temperature could free it. The sum of these losses is called loss on ignition. The temperature used was 600° C. for 45 minutes. The ignition loss is expressed as the percentage of the oven-dry weight.

(3) *Moisture Equivalent:* The procedure used in the determination of this constant is too well known to demand repetition. It is our best single value constant and is expressed as a moisture percentage.

(4) *Loss of Moisture Equivalent on Oven Drying:* Ordinarily, the moisture equivalent procedure is applied only to air-dry soils. The moisture equivalents of soils which have been oven dried are usually less than for air-dried soils. In the present study the moisture equivalent of the oven-dry soil was subtracted from that of the air-dry soil and the difference divided

by the air-dry moisture equivalent. This result is expressed as a percentage.

(5) *Wilting Percentage:* Although not a technical definition, the wilting percentage may be considered as the lowest percentage of moisture in a soil which will permit normal plant growth.

(6) *Phosphate Fixation:* The H. S. P. A. fixation kit was used to measure this constant. The procedure was slightly modified, however, so that comparable weight of soils might be exposed to the phosphate solution. Two grams of soil, on the oven-dry basis, were used in all cases. The values given are from the color comparison tubes provided with the kit.

(7) *Chemical Composition of the Colloidal Fraction:* It may perhaps be assumed that the active part of a soil is the finely divided material or the so-called "colloidal fraction." This material was separated from each of the soils and analyzed chemically. The best single value obtainable from such analyses seems to be the ratio of the oxide of silica to the oxides of iron and aluminum. This is reported as a molar ratio and listed as $\frac{\text{"SiO}_2\text{"}}{R_2O_3}$.

Since the organic matter would escape detection in the analysis suggested above, this constituent was determined independently. The results are listed under the head "Organic" and are expressed as percentages by weight.

The results of the determinations are given in Table II. Several generalities may be drawn at once from the data in Table II. The Maui soils, marked with an asterisk for convenience, are consistently high in volume weights and SiO_2/R_2O_3 ratios and consistently low in the other characteristics, including the organic matter in the colloidal fraction.

TABLE II

PHYSICAL CONSTANTS OF SELECTED SOILS FROM HAWAII AND MAUI

Soil No.	Vol. Weight	Loss on Ignition	M. E.	Per Cent Loss of M. E. on Oven Drying	Wilting Percentage	P_2O_5 Fixation	Composition of Colloidal Fraction $\frac{SiO_2}{R_2O_3}$	Organic
2*	0.96	15.2	33.1	3.9	25.9	0	1.44	1.1
3	0.52	35.9	68.0	44.5	48.2	80	0.50	10.7
4	0.59	26.0	57.4	24.5	51.3	80	0.75	7.0
5	0.87	17.0	36.8	12.5	29.0	40	0.90	3.3
6*	1.06	11.9	25.4	0.0	17.3	0	1.44	0.7
7	0.94	13.7	36.7	10.0	26.8	40	0.99	..
8	0.67	26.2	57.5	20.4	40.0	60	0.49	5.4
9	0.25	34.6	103.2	59.2	51.5	70	0.53	8.4
10	0.23	41.0	66.3	42.0	...	90	0.42	..
11*	0.98	12.4	30.8	4.2	22.7	0	1.86	1.4
12	0.57	28.5	58.0	28.6	37.5	50	0.41	8.8
13*	1.10	8.2	23.5	0.0	17.1	0	1.58	1.0
14	0.55	35.0	66.7	43.1	49.7	80	0.63	6.9
15*	1.05	10.9	27.5	8.2	18.8	0	1.55	0.9
16	0.14	22.0	297.0	89.5	173.1	90	0.38	4.0
17	0.38	34.2	105.0	71.0	73.8	80	0.42	6.8
18	0.55	30.0	56.0	51.3	46.7	80	0.59	5.5

The Kohala soils (5 and 7) seem more similar to the Maui soils than to those from Hamakua and Hilo.

As indicated in Table I, Soils 6 and 15 are from Maui Agricultural Company and were taken within a short distance of each other. Although Soil 15 is from a reputed "growth failure" area, the similarity of the soil constants for this soil and Soil 6, which is high producing, would indicate that the failure in Pulehu Field 85 was due to a chemical or biological condition and not to any physical characteristic.

A more comprehensive view of the interrelations indicated above is possible in the graphs.

Fig. 1 shows the relation between the volume weight and ignition loss. The correlation between the values is rather surprising as is the segregation of the soils in three general classes, which coincide with geographical position. Soil 16 is abnormal in most of its characteristics and widely escapes the correlation suggested in Fig. 1.

The same geographical segregation is noted in Fig. 2. Although the correlation between the factors considered in Fig. 2 is not lineal, as in Fig. 1, it seems none the less real. This condition may be brought about by the attempt to force the results from the fixation kit into quantitative aspects.

The non-lineal relation noted in Fig. 2 is again noted when the SiO_2/R_2O_3 ratio of the colloidal fraction is compared with the loss on ignition. Here, however, another possibility suggests itself. If the silica is associated with low ignition losses and the iron and alumina with high ignition losses, the hyperbolic nature of Fig. 3 would necessarily result in view of the SiO_2/R_2O_3 ratios used for the ordinates. Moreover, the relative richness of the Hamakua and Hilo soils in organic matter would tend to result in an increased loss on ignition.

The correlation coefficient between P_2O_5 fixation and the SiO_2/R_2O_3 ratios (Fig. 4) is —0.92, which is surprisingly high in view of the vagueness of the quantitative aspects of the P_2O_5 procedure. Here, again, one might expect a hyperbolic form of curve, as in Fig. 3.

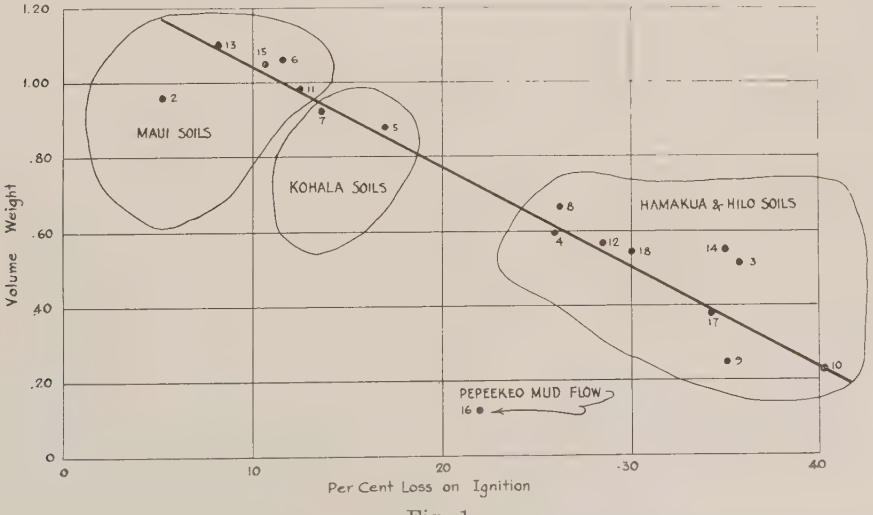

Fig. 1

The losses upon ignition for the seventeen soils as related to the volume weights.

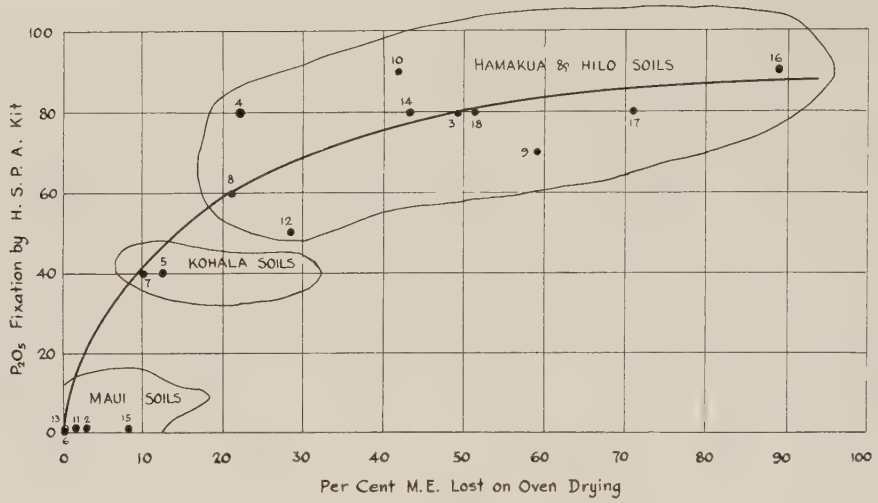

Fig. 2

The decreases in the moisture equivalents upon oven drying as related to phosphate fixation, as measured by the Experiment Station, H. S. P. A. fixation kit.

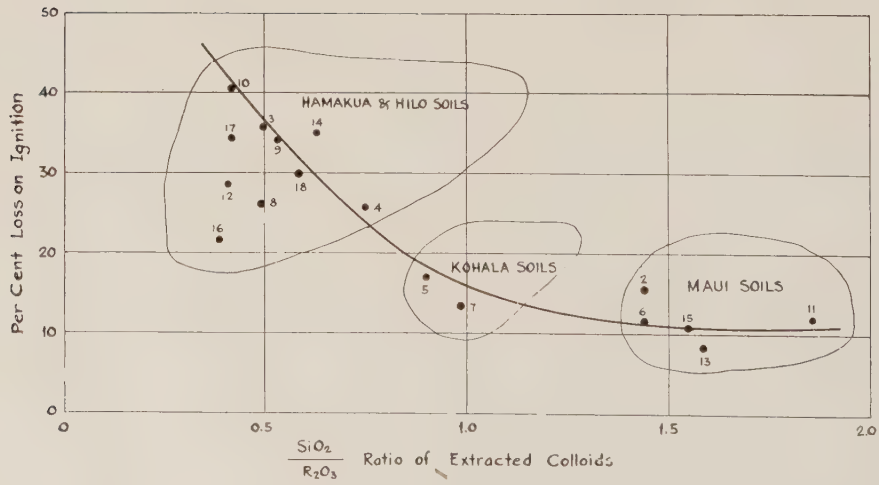

Fig. 3

The proportions of silica to iron and aluminum in the extracted colloid as related to ignition losses.

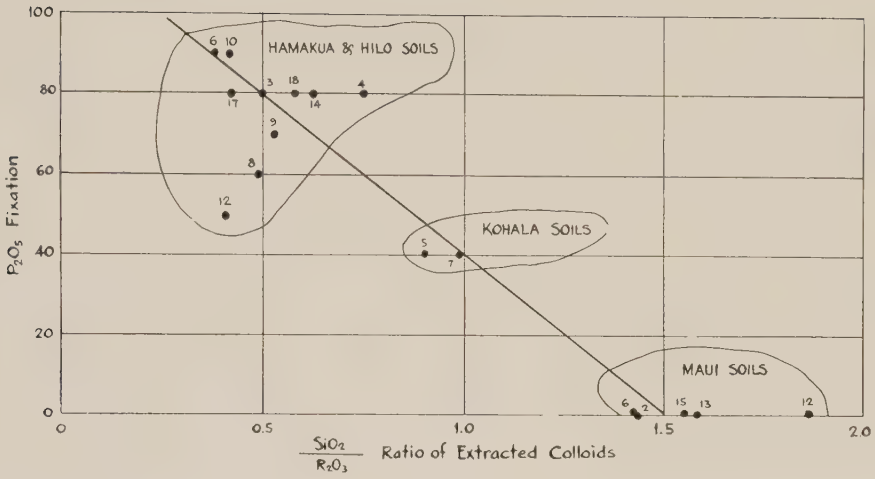

Fig. 4

The ratios of silica to iron and aluminum in the extracted colloids as compared to the phosphate fixation, as measured by the Experimental Station, H. S. P. A., fixation kit.

Discussion

Several interesting suggestions are offered in the results presented above. In perfect accord with the argument of some recent workers in the study of soil origin, we find soils rich in colloidal iron and alumina and lean in silica on the windward or rainy sides of the two islands reported, while in drier regions the silica seems the more permanent, iron and alumina being lost by leaching. The reason for this differential leaching is not perfectly understood; the arguments advanced to support the opinions offered need not concern us. Be the cause what it may, most modern workers are convinced that continuous leaching results in a soil that is lean in SiO_2 and relatively rich in the oxide of iron and aluminum. Again in accord with popular opinion, the soils from the regions of high rainfall carry more organic matter than others, partly perhaps because the organic matter is more rapidly formed in such locations, but also because it is more slowly decomposed.

The data also suggest that other modifications of the soil take place during the leaching process along the rainy coasts of Hawaii. These soils absorb and hold large amounts of water either because of the fine grain sizes involved or because of chemical hydration. Two soils from Hamakua Mill Company (18 and 17) held 52 per cent and 86 per cent of their oven-dry weight as moisture when in a so-called "air-dry" condition. This absorption or adsorption of water tends to bring about a low volume weight since only the oven-dry material is used in the computation of this characteristic. Fig. 1 seems to support the conclusion that volume weight decreases as rainfall increases. A study of the value of this correlation with modern rainfall records does not seem of great value.

As has been indicated, large amounts of water are tightly held by soils of the Hamakua region. Consequently, the moisture equivalents of these soils are high.

When oven dried, however, a large part of this water is driven off; nor can it be immediately replaced by again saturating the soil as is done in the moisture equivalent procedure. This irreversible process is well illustrated by the sample from the mud flow area above Pepeekeo (16). In its original air-dry condition this soil had a moisture equivalent of 297 per cent. When oven dried, a process which resulted in great loss of volume, a moisture equivalent of 31.4 per cent was observed, or a loss of 89.5 per cent.

The ignition loss, too, seems closely related to the conditions of weathering through which the soil was formed. Although the Hamakua soils are richer in organic matter than those from central Maui, it seems illogical to assume that the great differences in ignition loss are due to this factor. A more logical explanation seems to lie in the belief that large amounts of water are combined with the Hamakua soils and are so tightly held by some physical or chemical bond that a temperature of 110° C. fails to liberate it.

The phosphate-fixing aspects of the soils are not as readily visualized as the other characteristics. Regardless of the causal relation and assuming that the phosphate fixation kit may with proper precaution be used as a rough quantitative measure of the tendency for a soil to fix phosphate, we see a steady and continuous increase in this tendency as the intensity of the weathering increases. Since there seems to be no such continuous increase in the percentage of colloidal matter in the soil as measured either by the hydrometer or by the heat of wetting, one naturally turns to the nature of the colloidal matter involved in an effort to interpret the relation which seems to exist. From the many analyses of similar material reported in the literature, it is evident that about 90 per cent of the colloid is a mixture of oxides or compounds of silica, iron and aluminum together with the material lost on ignition, which includes organic matter. Most writers have used the ratio secured by dividing the number of moles of SiO_2 by the sum of the moles of Al_2O_3 and Fe_2O_3 to express the chemical and physical activity of the colloid. In the present case, the correlation coefficient of —0.92 between this ratio and our measure of phosphate fixation seems highly significant. Regardless of the chemistry involved, we have some statistical evidence, questionable as it may be, that an abundance of colloidal iron and aluminum would tend to fix phosphate, while any silica present not only failed to fix this material but seems to actually depress the fixing ability of the iron and aluminum present.

This possibility was explored by assuming that each mole of SiO_2, Al_2O_3 and Fe_2O_3 had the capacity of fixing a certain weight of soluble phosphate, and from the seventeen equations available computing the values indicated. The most plausible values secured by the methods of normal equations were:

Al_2O_3=2.07 units of fixation per cent.
Fe_2O_3=2.18 units of fixation per cent.
SiO_2=—2.56 units of fixation per cent.

When the computed fixations of the soils upon the basis of their chemical analysis and the constants given above are compared with the observed values, a correlation coefficient of +0.82 is secured.

Although such a procedure may be highly questionable, it might be interpreted

to give some additional evidence that silica in the soil colloid may offset the fixing powers of aluminum and iron which may be present. Recent efforts by some plantations to reduce the phosphate-fixing character of their soils by adding soluble silicates should be noted in this connection.

Summary

(1) The physical properties of seventeen typical soils from Maui and Hawaii are given as a result of recent work at the University of Hawaii.

(2) The nature of the soils as measured by the physical properties mentioned seems to depend upon the conditions of weathering under which the soils were formed. Soils from windward Hawaii are characterized by low volume weights, high ignition losses and high phosphate-fixing characteristics. Soils from Maui exhibit high volume weights, low ignition losses, and little or no phosphate fixing capacity. The interrelations of these characters are illustrated by graphs.

(3) The results from a "growth failure" area at Maui Agricultural Company as compared with a neighboring area, indicate that the failure is not traceable to a physical characteristic of the soil.

(4) Some evidence is offered that phosphate fixation in the local soils is due to an abundance of iron and aluminum in the colloidal separate of the soil. Moreover, the presence of silica in the colloidal separate seems to act as if it had the capacity of minimizing the fixative characteristic of the iron and aluminum with which it is associated.

Investigation of the Effect on the Strength of Lime Mortar by the Addition of Molasses

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By J. A. Swezey

This investigation was made to determine what effect the addition of molasses to lime mortar had on the strength of the mortar.

Drs. Gerald J. Cox and John Metschl, of the Mellon Institute of Industrial Research (*Rock Products*—May, 1932, and *Sugar Bulletin*—May, 1932), reported early in 1932 that when sugar equivalent to 6 per cent by weight of quicklime was added to lime mortar, the tensile strength of the mortar was increased by 60 per cent (approximately) at an age of 6 months.

Cox and Metschl in their report gave very little information as to their procedure of testing other than to mention briefly the proportions of lime, sand, and water used to make the mortar, and that they used A. S. T. M. standard tensile briquette molds.

The procedures employed in the present investigation followed as nearly as possible the specifications of the A. S. T. M. Inasmuch as this society has not yet adopted a standard method of testing the strength of lime mortar, the methods

described below are to some extent original and were designed to give the most practical comparative tests possible.

The present investigation was conducted in the engineering laboratory of the University of Hawaii by the writer, assisted by A. H. Cornelison.

Materials Used

Quicklime—Roche Harbor Brand—manufactured at Roche Harbor, Wis. (Supplied by courtesy of Lewers & Cooke, Ltd., Honolulu.)

Sand—20- to 30-mesh, standard Ottawa sand.

Water—Tap water from Honolulu water supply system.

Sugar—Commercial refined sugar (supplied by sugar technology department of the Experiment Station, H. S. P. A.)

Molasses—Straight commercial run of molasses (supplied by Oahu Sugar Company) having the following analysis:

Gravity solids	95.35%
Sucrose	33.40%
Gravity purity	35.03%
Glucose	16.74%
Ash potash	13.33%

Brick—Red *pressed* brick, used to make up certain test samples. Dimensions: 8¾" x 2 7/16" x 4 3/16".

Apparatus

Molds—Standard A. S. T. M. briquette, cube, and cylinder molds.

Machines—Riehlé Briquette Testing Machine.

Olsen 20,000 lb., Universal Testing Machine. Riehlé 150,000 lb., Universal Testing Machine.

Mixing and Molding

The batches of mortar were mixed as follows: The lime was slaked by adding 2¾ parts of water to 1 part of lime (by weight). The resulting paste or putty was stirred for 3 hours and then daily until used. The first group of samples was made with putty aged only 24 to 48 hours. Early tests of samples at an age of 8 weeks indicated that a longer period of aging for the putty was required. A second group of samples was therefore made of putty aged 2 weeks or more. Putty aged at least two weeks was quite free of unslaked lime grains, which in short-aged putty undoubtedly weakened the sample pieces by "exploding" during the setting of the mortar.

To the lime putty was added 3 parts, by weight, of 20-30 mesh standard Ottawa sand to 1 part of unslaked lime. The putty and sand were thoroughly mixed into a mortar, to which was added the desired amount of adulterating molasses dissolved in ¼ part of water to the 1 part of unslaked lime.

The final proportions of the mortar were then:

1 part unslaked lime
3 parts standard sand
3 parts water
"X" parts molasses

Note:—One set of samples was made of mortar containing 6 per cent of refined sugar, to compare with the results reported by Cox and Metschl.

As soon as each mortar batch was thoroughly mixed it was placed in the various molds, being pressed and tamped well to occlude air bubbles. The molds were removed immediately the mortar had attained sufficient set to maintain shape unsupported.

Some interesting observations were made as follows:

(a) Molasses and mortar, mixed in equal parts, generated considerable heat. Sugar and mortar, mixed in equal parts, did not generate any noticeable heat.

(b) The molasses stained the mortar to a brown color, the greater the amount of molasses in the mortar the darker the color. Apparently in the more slushy mixes the molasses floated to the top of the samples during the "initial set" period, thus staining the top surface more than the interior.

(c) Unless the putty was thoroughly stirred and aged, plain mortar shrank unevenly, causing checks and cracks to appear in the sample pieces, thus weakening them. The addition of molasses tended to relieve this condition, the molasses apparently having a binding effect.

(d) Mortars containing 6 per cent or more of sugar or molasses were quite fluid and slow to set, the degree of fluidity and the time of set increasing with increase in the proportion of the sucrose present in the mortar.

Description of Sample Pieces

Briquettes. Briquettes, formed in the standard A. S. T. M. molds, were originally to be subjected to the tension test for which this type of sample is especially designed, but as will be explained under "Description of Tests," they were finally tested under compression.

Cubes. With A. S. T. M. molds, 2-inch cubes were made. These cubes were tested in compression.

Cylinders. With A. S. T. M. molds, 2-inch diameter x 4-inch long cylinders were made for compression tests. Cylinders of 1:3 lime mortar only were made, for a comparison with the other types of samples.

Brick Masonry. To make practical comparative tests of the strength of the various mortars, red pressed-brick were set up with the mortar in the joints.

The samples thus made each consisted of two bricks laid together edgewise with a mortar joint approximately ¼″ to ⅜″ thick.

Description of Tests

Briquettes. At an age of 6 months an attempt was made to test the briquettes under a tension load; however, in the tension testing machine the briquettes did

not fail across the smallest cross-sectional area (1 sq. inch), but the failure occurred in either one of two planes of shear, indicated in Fig. 1A.

Since it was evident that the briquettes would not give satisfactory comparative tensile strength tests, they were subjected to compression, applied perpendicularly to the flat surfaces. (See Fig. 1B.)

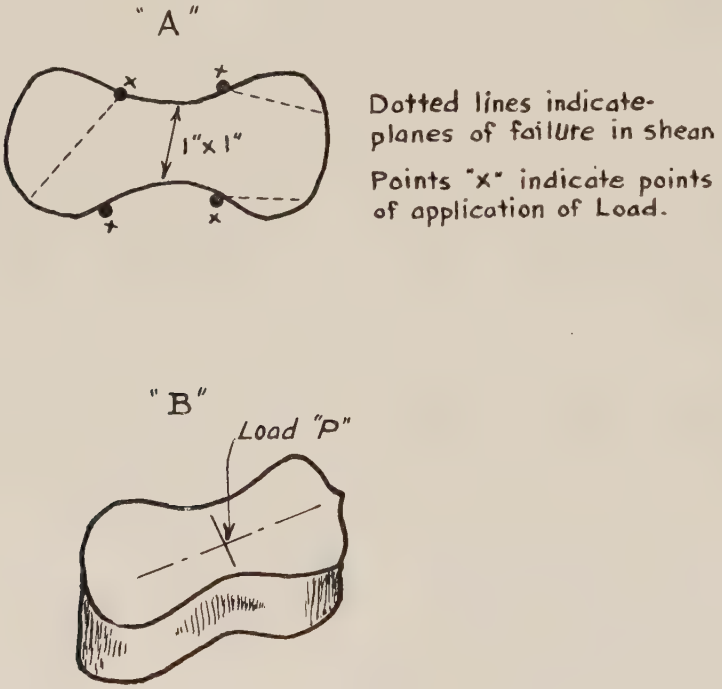

Fig. 1

The area to which the load "P" was applied was obtained by laying each briquette on a sheet of paper and drawing around the edge with a sharp pencil. The outline thus drawn was measured with a planimeter to give the area in square inches.

The compression test of the briquettes proved very satisfactory. The compression load was increased to a point of complete, or ultimate, failure of the briquettes. The point of failure was easily detected by the customary "drop of the beam" of the testing machine's scale.

Ultimate failure consisted of a sudden, complete disintegration of the briquette under test. The load recorded by the machine at this point of failure was divided by the area of the top of the briquette to give the unit compressive strength in pounds per square inch.

Seven to ten briquettes constituted a test, and the average unit compressive strengths of the various batches of mortar are reported in Table I. The data are plotted as curves in Fig. 2 (A). Several batches were tested at an age of nine months, as shown in the table and curves.

It is seen that up to 6 per cent adulteration of the lime mortar with molasses produced a marked increase in the strength of the mortar. Adulterations of over

6 per cent of molasses produced strengths slightly less than for 6 per cent, but still much greater than that of unadulterated mortar.

The curve for per cent increase in strength follows closely the shape of the strength curve.

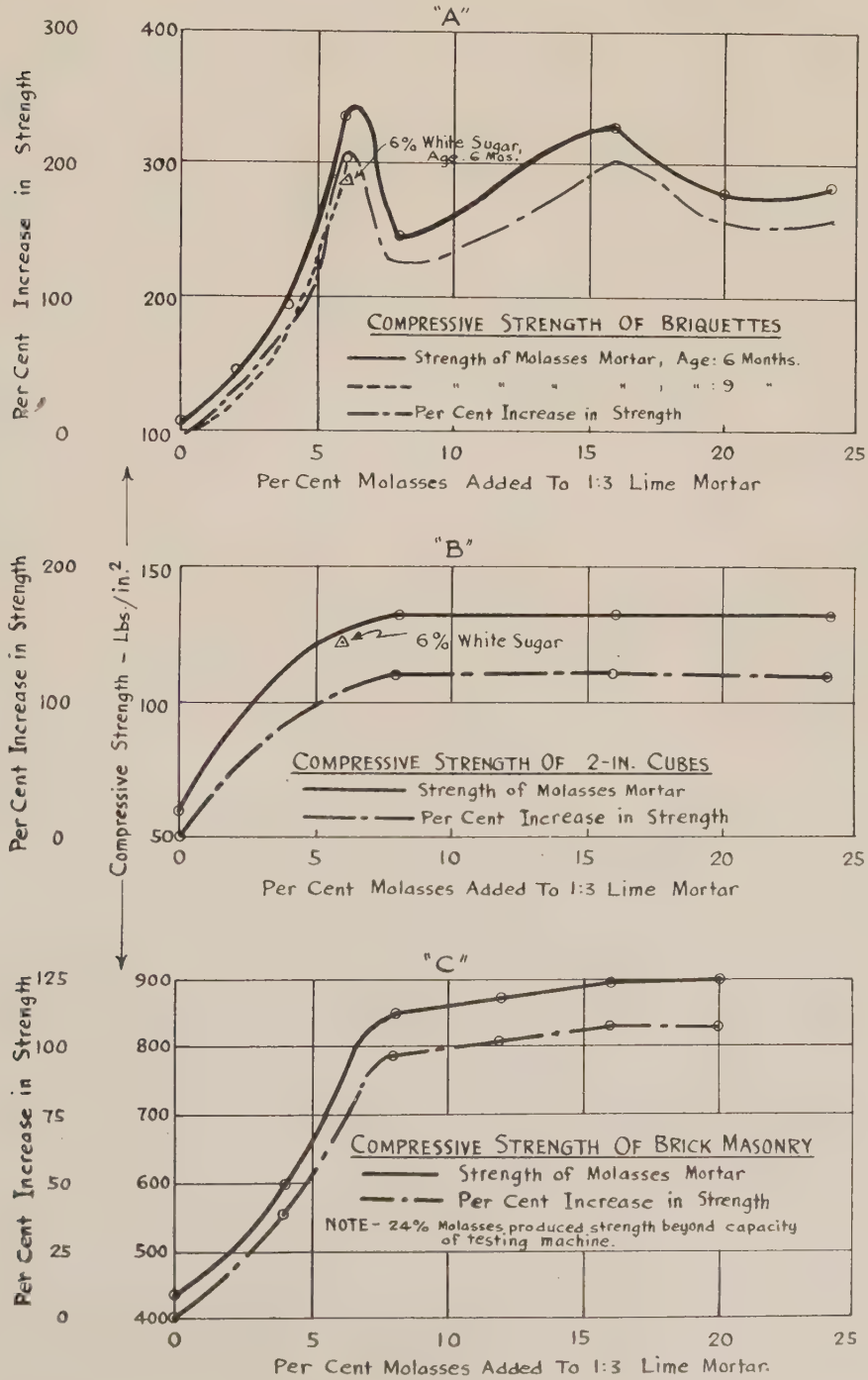

Fig. 2

At 9 months of age the strength was slightly less than at 6 months, although the difference was insignificant, considering that lime mortar requires a long period of time for attaining complete "set."

Six per cent white sugar produced almost as great an increase in strength as 6 per cent of molasses.

Cubes. At an age of 6 months the 2-inch cubes were tested in compression. As with the briquettes the point of complete failure was readily detectable by the "drop of the beam."

The data on strengths appear in Table II and Fig. 2 (B).

The strengths of the cubes are lower than for the briquettes, but again a maximum strength was produced by 6 per cent adulteration with molasses, with no further increase in strength produced by still greater adulteration.

Brick Masonry. These samples were also tested in compression. The point of failure was difficult to detect as no drop of the beam was observable up to the loading capacity of the 20,000-pound Olsen machine.

In the Riehlé 150,000-pound machine, a sample was tested to 40,000 pounds, at which load the bricks failed.

However, the mortar joint was observed, as the load was gradually increased, to swell, followed by peeling off of the harder outside skin of mortar, and finally forcible throwing out from the surface of the joint of sand grains and lime particles. This latter phenomenon was considered to indicate failure, by crushing, of the interior of the mass of lime forming the joint.

The large ratio of area to thickness of mortar accounts for no drop of the beam at failure of the mortar. Therefore, the load was increased from "0" until sand and lime began to drop out of the joint; the load at this point was taken as the failure load and used to compute the unit strength.

In spite of the difficulty of detecting failure of these samples the data and curves (Table II and Fig. 2 [C]) show strengths parallel to the other types of samples, i.e., increase of strength with increasing adulteration up to 6 per cent, then no additional increase of strength beyond 6 per cent adulteration.

Cylinders. The 2-inch diameter x 4-inch-high cylinders of 1:3 mortar were tested in compression, to complete failure. Table III shows the strengths of 1:3 mortar briquettes, cubes, brick masonry, and cylinders compared with the corresponding heights, or thicknesses of mortar also tabulated. The data are plotted in Fig. 3—strength vs. thickness. The curve presents a guide to the strengths that may be expected from various thicknesses of mortar, and is exhibited to explain why, with any one of the given per cents of adulteration, the strengths vary so greatly between types of samples. It is natural to expect that the thinner the mortar the greater the unit strength.

Summary and Conclusions

In this investigation lime mortar was subjected to compression tests unadulterated and adulterated with varying percentages of molasses.

Compression tests were employed rather than tension tests, because compres-

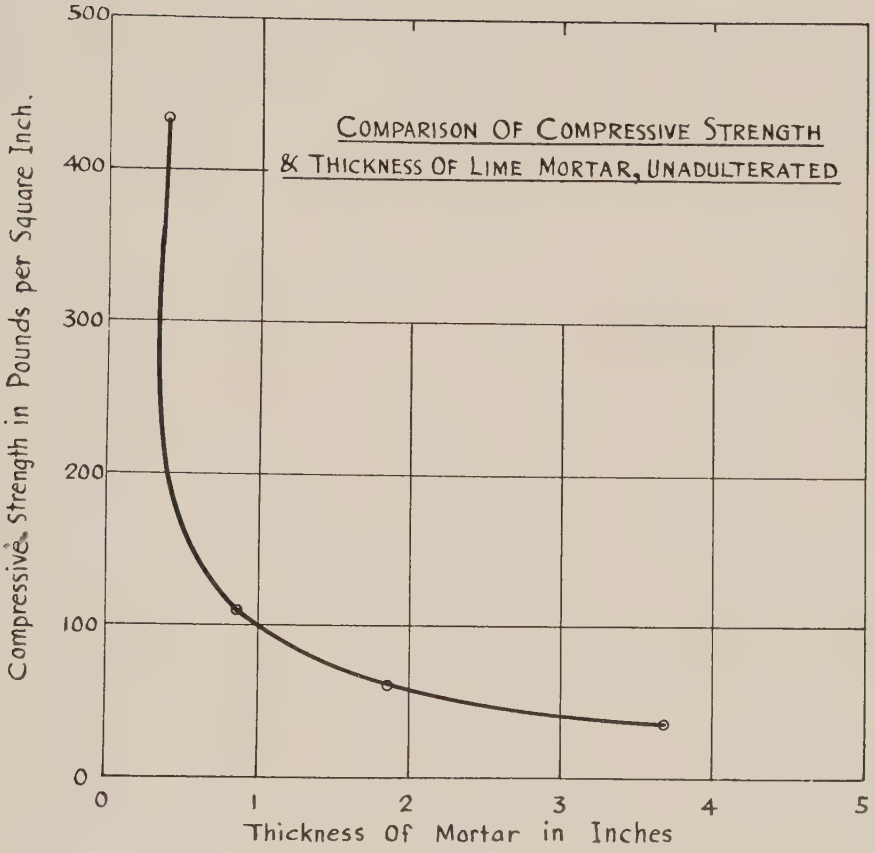

Fig. 3

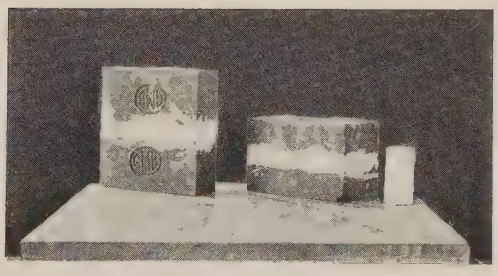

Fig. 4

sion tests were considered of more practical value, lime mortar seldom, if ever, being used in situations where it would be under tensile stresses.

From the results of these tests as shown in the tables of data and the curves, the following conclusions can be made:

1. That the addition of 6 per cent of sugar will increase the *compressive* strength of lime mortar by 165 per cent. This is a far greater increase in

strength than that obtained by Cox and Metschl (60 per cent in tension), but it must be borne in mind that the compressive strength of cements, concrete, and mortars is greater than the *tensile* strength; hence any increase in strength would be much greater compressively than the corresponding increase in tensile strength.

2. That as molasses is added to lime mortar from 0 to 24 per cent adulteration, the compressive strength is increased. However, the *maximum* increase in strength was produced by 6 per cent adulteration with molasses, this increase being 206 per cent. Note that increasingly larger amounts than 6 per cent of adulteration with molasses produced increases in strength over the strength of unadulterated mortar, but these increases in strength were somewhat less than that produced by 6 per cent adulteration.

3. That molasses added to lime mortar produced a better mortar than the addition of sugar. Not only was the maximum attainable increase in strength (with 6 per cent adulteration in both cases) greater for molasses than for sugar (206 per cent increase against 165 per cent), but a more perfectly setting mortar was obtained by adding molasses. A molasses-adulterated mortar set with few, if any checks or cracks. Also, with equal amounts of adulteration with molasses and sugar, a somewhat less fluid mix was produced by the molasses. The degree of checking and cracking has a very direct bearing on the obtainable strength of mortar.

4. No definite conclusion can be stated with respect to the comparison of strengths at 6 and 9 months of age (see Table I), since the mortar tested at 9 months of age was made from lime putty insufficiently cured. However, the comparison does show that ageing quite possibly will not overcome the harmful effects of short-curing of the lime putty.

5. That the greater the thickness or height of the lime mortar, the less will be its strength. However, molasses adulteration still increases the strength of mortar more than does sugar, even in samples of large thickness.

TABLE I

UNIT COMPRESSIVE STRENGTHS OF BRIQUETTES OF 1:3 STANDARD SAND-LIME MORTARS CONTAINING VARIOUS AMOUNTS OF MOLASSES

(Note—Figures in parentheses are number of samples to each test.)

Per cent (by weight) of Adulteration	Age—6 Months			Age—9 Months		
	Lbs./in.² Compressive Strength	Difference from 0% Adulteration		Lbs./in.² Compressive Strength	Difference from Age of 6 Months	
		Lbs./in.²	Per cent		Lbs./in.²	Per cent
0	109 (10)	0	0	99 +	—10	— 8.85
6 (sugar)	289 (10)	+180	+165	265 (10)	—24	— 8.3
2 (molasses)	146 (8)	+ 37	+ 34	129 (10)	—17	—11.6
4 "	195 (8)	+ 86	+ 79	183 (10)	—12	— 6.2
6 "	333 (8)	+224	+206	302 (9)	—31	— 9.3
8 "	246 (7)	+137	+126	.....	....	.....
16 "	327 (8)	+218	+200	.....	....	.....
20 "	276 (2)	+167	+153	.....	....	.....
24 "	282 (7)	+173	+159	.....	....	.....

(+Computed from average of differences below.)

TABLE II

UNIT COMPRESSIVE STRENGTHS OF CUBE AND BRICK SAMPLES OF 1:3 STANDARD SAND-LIME MORTARS CONTAINING VARIOUS AMOUNTS OF MOLASSES

(Note—Figures in parentheses are number of samples to each test.)

Per cent (by weight) of Adulteration	2-inch Cubes			Brick Masonry		
	Lbs./in 2 Compressive Strength	Difference from 0% Adulteration		Lbs./in 2 Compressive Strength	Difference from 0% Adulteration	
		Lbs./in 2	Per cent		Lbs./in 2	Per cent
0	60 (4)	0	0	433 (2)	0	0
6 (sugar)	146 (4)	+86	+143	.....	.....	.....
4 (molasses)	.....	....	.....	596 (4)	+163	+ 38
8 "	132 (4)	+72	+120	850 (4)	+417	+ 96
12 "	.....	....	.....	869 (6)	+436	+101
16 "	132 (4)	+72	+120	895 (6)	+462	+107
20 "	.....	....	.....	898 (5)	+465	+107
24 "	132 (4)	+72	+120	938+(6)	+505	+117

TABLE III

COMPARISON OF COMPRESSIVE STRENGTHS OF PLAIN 1:3 STANDARD SAND-LIME MORTAR BRIQUETTES, CUBES, CYLINDERS AND BRICK MASONRY, SHOWING RELATION OF THICKNESS TO STRENGTH OF MORTAR

Type of Sample	Compressive Strength (Lbs./in 2)	Height or Thickness of Mortar (inches)
Brick masonry	433	0.375
Briquettes	109	0.875
Cubes	60	1.875
Cylinders	36	3.688

Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD
DECEMBER 17, 1932, TO MARCH 15, 1933

Date	Per Pound	Per Ton	Remarks
Dec. 17, 1932	2.85¢	$57.00	Cubas.
" 21	2.82	56.40	Cubas.
" 22	2.80	56.00	Cubas.
" 27	2.79	55.80	Puerto Ricos, Philippines.
" 28	2.765	55.30	Puerto Ricos, Philippines, 2.75; Cubas, 2.78.
" 29	2.78	55.60	Cubas.
Jan. 3, 1933	2.77	55.40	Philippines.
" 4	2.785	55.70	Puerto Ricos, Philippines.
" 9	2.78	55.60	Philippines.
" 12	2.75	55.00	Cubas.
" 13	2.73	54.60	Puerto Ricos.
" 16	2.70	54.00	Puerto Ricos, Philippines.
" 17	2.67	53.40	Puerto Ricos.
" 26	2.68	53.60	Puerto Ricos.
" 27	2.70	54.00	Puerto Ricos, Philippines.
" 30	2.68	53.60	Philippines.
Feb. 1	2.66	53.20	Philippines, Puerto Ricos.
" 2	2.65	53.00	Philippines.
" 8	2.69	53.80	Puerto Ricos, 2.68; Puerto Ricos, Philippines, 2.70.
" 10	2.70	54.00	Philippines, Puerto Ricos.
" 15	2.72	54.40	Puerto Ricos.
" 16	2.80	56.00	Philippines.
" 23	2.825	56.59	Cubas, Philippines, 2.85; Puerto Ricos, 2.80.
" 24	2.85	57.00	Puerto Ricos, Cubas.
" 27	2.80	56.00	Cubas.
" 28	2.85	57.00	Cubas.
Mar. 3	2.86	57.20	Puerto Ricos, 2,85; Cubas, 2.86; Puerto Ricos, 2.87.
" 4	2.90	58.00	Puerto Ricos.
" 6	3.00	60.00	Cubas.
" 7	3.025	60.50	Philippines, 3.00; Puerto Ricos, 3.05.
" 8	3.00	60.00	Puerto Ricos.
" 10	2.96	59.20	Puerto Ricos.
" 15	3.00	60.00	Cubas.